# Embracing the Future:
## Promoting adaptation and resilience to invasive species and climate change


## Summary

Climate change and invasive species can interact to increase disturbances and magnify changes in ecosystem form and function (Double Trouble). Increasing resilience is one of several management approaches for enabling healthy ecosystems to persist despite these changes. While resilience can be complicated and take many forms, it can generally be thought of as the "ability [of an ecosystem] to experience disturbances or environmental change without changing to a fundamentally different state" [Holling, 1973].

The accumulating effects of climate change, invasive species, or interacting effects of multiple disturbances can push an ecosystem past a tipping point and into a new ecological state. These alternative states are characterized by a different suite of species or functions, which are difficult or impossible to recover from (e.g. a shift from a closed-canopy to an open-canopy forested wetland). Actions to increase resilience help an ecosystem to maintain or return to its fundamental structure or function after a disturbance.

Resilience falls in the middle of a spectrum of management goals ranging from preventing change (resistance) to promoting change (transformation) in the species composition, structure, or functions provided by an ecosystem. Clear management goals (See Table) and an understanding of the range of disturbances affecting focal ecosystems are necessary for deciding between managing for resistance, resilience, or transformation and what actions are required for successful management outcomes.


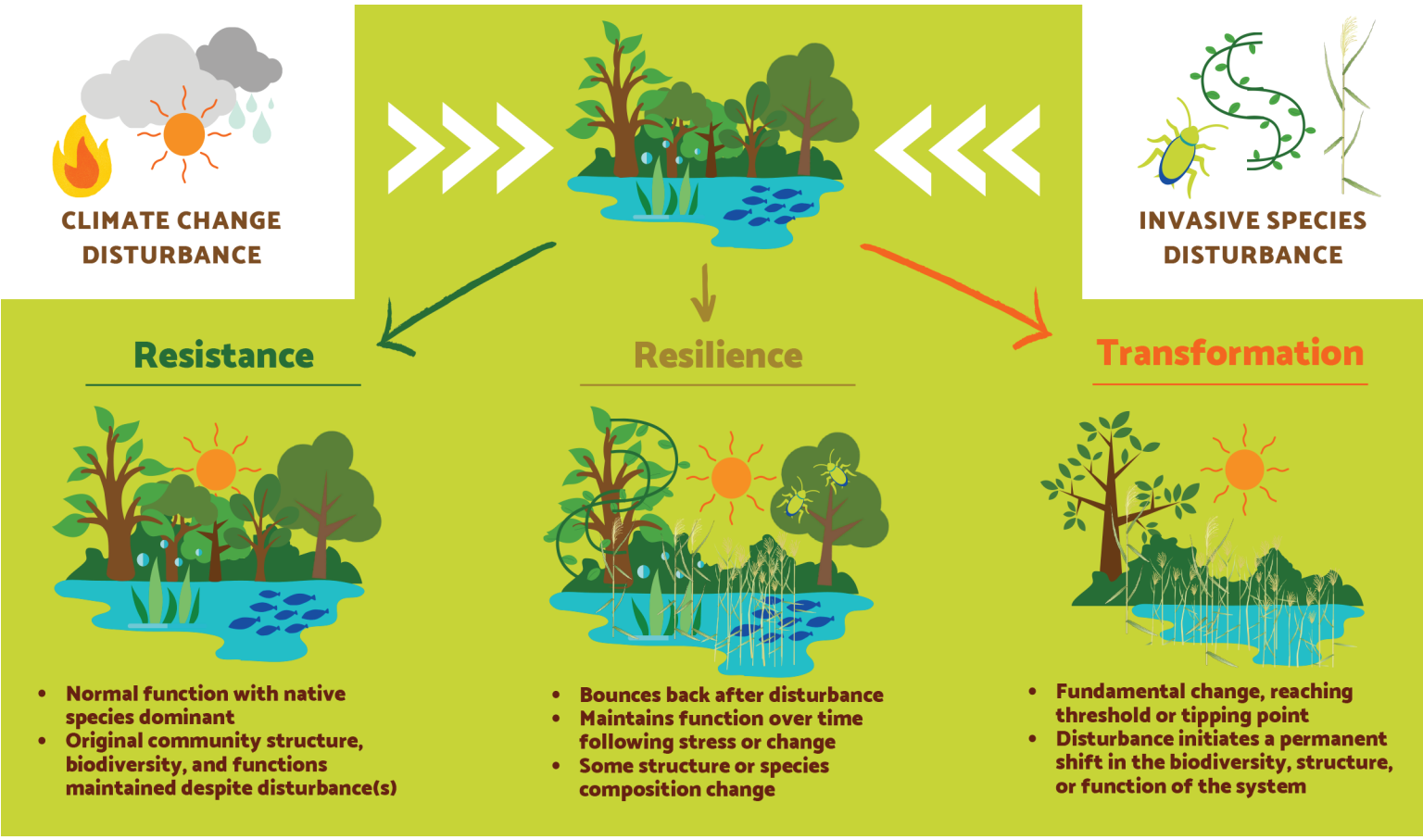


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**Table** Management actions and approaches given desired management goals for ecosystem responses to disturbances.

*Resist change* ← → *Direct change*

| | Resistance | Resilience | Transformation |
|---|---|---|---|
| | Actions designed to maintain current or focal (e.g., threatened) species composition, ecosystem structure, or functions. | Actions that allow for some changes following a disturbance while enabling the system to return ("bounce back") to a state similar to pre-disturbance. | Actions that allow or facilitate the transition of a system to a new state characterized by new species, structures, or functions. |
| *General management strategies* | • Prevent invasion through policy or monitoring<br>• Eradicate harmful invasives<br>• Maintain and/or conserve existing native biodiversity<br>• Reduce climate stress | • Promote biodiversity at multiple levels (e.g., genetic, species, functional groups)<br>• Increase habitat connectivity<br>• Maintain historical disturbance regimes<br>• Support growth and vigor of focal populations | • Encourage or facilitate the migration of species or populations that are adapted to future climates<br>• Allow species that contribute to ecosystem function to persist, including non-natives |
| *Example management strategies for emerald ash borer (EAB)*  | • Active thinning of ash stands to promote tree health in light of climate stress<br>• Chemical treatment of trees to resist the invasion of EAB into a specific location<br>These treatments can be costly, so resistance strategies are usually reserved for special and/or unique groves or a few specific ash trees, particularly if these areas are climate refugia or culturally significant. | • Silvicultural treatments that increase the overall health of the forest stand to promote the resilience of the ecosystem after the invasion of EAB<br>Treatments increase the health or abundance of complementary or native species that are predicted to do well with climate change (e.g., red maple, swamp white oak). Some ash can be kept as seed sources for future regeneration with the hopes of the stand eventually returning to a state close to its current condition. | • Passive or active management, (e.g., planting) to encourage stands with significant amounts of ash to transition to a new composition and/or function.<br>Inaction can lead to a transition of a closed-canopy ash wetland to an open wetland or provide opportunities for additional invasives. New openings from ash mortality or management can create opportunities to plant climate-adapted species, transitioning the stand composition while maintaining ecosystem functions. |

Left: Managers and researchers reviewing adaptation options for an ash stand in Vermont in response to EAB and Climate Change. Photograph by: Tony D'Amato, UVM.


**References:**

Bradley et al. 2019 (Double Trouble: https://scholarworks.umass.edu/eco_ed_materials/5/); Holling 1973 Annu. Rev. Ecol. Evol. Syst.; Morecroft et al. 2012 J. Appl. Ecol.; Nagel et al. 2017 J. For.; Peterson St-Laurent 2021 Comm. Biol.; Swanston et al. 2016, USFS; Schuurman et al. 2020., National Park Service.


EAB photo captured with the Macropod PRO 3D provided by Macroscopic Solutions.


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NYISRI New York Invasive Species Research Institute